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AN ALTERNATING TEST METHOD FOR CONCRETE PERMEABILITY

T.J. Zhao,[1]* Z.H. Zhou,* J.Q. Zhu,† and N.Q. Feng†
*Department of Civil Engineering, Qingdao Institute of Architecture and Engineering, Qingdao 266033, Peoples Republic of China
†Department of Civil Engineering, Tsinghua University, Beijing 100084, Peoples Republic of China

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ABSTRACT

ASTM C1202 is now the most common concrete permeability testing method used world wide, and also the method receiving most of the criticisms and doubts. Concrete resistance is measured with alternating current, and the conductance calculated to reflect its permeability. With various concretes, experiments show that the conductance of the alternating current method and the charge of ASTM C1202 correlate well, with the coefficient of 0.9867. Accordingly, the specification of concrete permeability measured by alternating current is set up. © *1998 Elsevier Science Ltd*

Introduction

As more and more concrete structures prematurely deteriorated in recent years, concrete durability has been treated conscientiously. Because concrete durability includes many aspects, and is influenced by many factors, its mechanism is so complex that the current science seems inadequate (1). It is found that concrete permeability is one of the intrinsic properties of concrete, and has direct relations to its durability (1–5). As a result, concrete permeability becomes one of the hot spots in concrete durability researches.

There are many testing methods for concrete permeability, each of them has some shortcomings, among which ASTM C1202 (6) is the most commonly used method world wide, and also the method receiving most of the criticisms and doubts (7). From attainable literature, electricity was first used to measure concrete resistance in the fifties (8). Later on, many application reports appeared for various purposes, including to reflect concrete permeability (9–20), among which References (16) and (17) made some valuable comparisons between results of alternating current method and ASTM C1202, and even gave some correlation relations, though they used much fewer kinds and numbers of concrete. As the present authors prefer the alternating current method to ASTM C1202, and have the intention to set up a new specification of test method for concrete permeability, they did a lot of research on pure cement concrete, and concrete with some fly ash, slag, silica fume, or zeolite

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[1]To whom correspondence should be addressed.

as part of the replacement of cement, with large dosage of $NaNO_2$ as chemical admixture in order to induce more free ions to the concrete, or with changing content of water or binding materials. This paper reveals some of the results.

Materials and Mix Proportions

The following materials were used: a river sand, with particle size as in Table 1; two kinds of limestone, one (Stone #1) unwashed with 0.93% of silt, the other (Stone #2) washed, with particle sizes as in Table 2; two kinds of 525R (Chinese Standard) Portland cement, a ground slag, a fly ash, and a zeolite powder, with chemical compositions shown in Table 3; a powder NF superplasticizer; and a $NaNO_2$ chemical reagent ($\nless$99.0%).

TABLE 1
Accumulative residue of sand on different meshes.

Mesh (mm)	5.00	2.50	1.25	0.63	0.315	0.16	$<$0.16
Accumulative Residue (%)	0	20.0	37.2	55.2	72.8	79.4	99.0

TABLE 2
Accumulative residue of stone on different meshes.

Mesh (mm)		25	20	15	10	5	$<$5
Accumulative	Stone #1	0	10.6	49.5	90.6	97.6	100
Residue (%)	Stone #2	0	10.7	50.0	91.4	98.5	100

TABLE 3
Results of analysis for cements and mineral admixtures.

Items	Cement #1	Cement #2	Silica Fume	Slag	Fly Ash	Zeolite
Chemical Composition (%)						
SiO_2	25.26	21.93	91.76	40.00	52.80	71.13
Al_2O_3	7.71	5.60	1.42	8.91	29.20	13.52
Fe_2O_3	4.45	3.97	1.17	0.72	6.28	2.23
CaO	57.89	61.16	0.69	38.78	5.45	6.36
MgO	1.98	4.35	0.73	9.35	1.96	1.65
K_2O	1.04	1.46	2.64	0.68	1.34	2.88
Na_2O	1.10	1.10	1.13	0.71	1.26	1.74
MnO	0.04	0.07	0.11	0.27	0.06	0.02
TiO_2	0.30	0.34	0.02	0.38	1.28	0.25
P_2O_5	0.16	0.16	0.24	0.15	0.33	0.18
Specific Gravity (g/cm^3)	3.05	3.05	2.16	2.90	2.13	2.37
Specific Surface (cm^2/g)	3794	3596	190000	4322	5863	10116

TABLE 4
Codes and proportions of concrete.

			Binding Materials									
			Cement			Mineral Admixtures				Stone		NF (% by Cement Weight)
Code	W/B	Water (kg)	Type	Ratio (%)	Weight (kg)	Type	Ratio (%)	Weight (kg)	Sand (kg)	Type	Weight (kg)	
1	0.35	175	#1	100	500	/	/	/	700	#1	1100	1.2
2	0.35	175	#1	100	500	/	/	/	700	#1	1150	1.0
3	0.35	175	#1	90	450	Silica Fume	10	50	700	#1	1150	1.2
4	0.35	175	#1	60	300	Slag	40	200	700	#1	1150	1.1
5	0.35	175	#1	60	300	Fly Ash	40	200	700	#1	1150	1.0
6	0.35	175	#1	90	450	Zeolite	10	50	700	#1	1150	1.2
7*	0.35	175	#1	100	500	/	/	/	700	#1	1150	1.0
PW0	0.30	150	#2	100	500	/	/	/	700	#2	1150	1.6
KW0	0.30	150	#2	70	350	Slag	30	150	700	#2	1150	1.8
FW0	0.30	150	#2	70	350	Fly Ash	30	150	700	#2	1150	1.6
PW3	0.33	165	#2	100	500	/	/	/	700	#2	1150	1.2
KW3	0.33	165	#2	70	350	Slag	30	150	700	#2	1150	1.4
FW3	0.33	165	#2	70	350	Fly Ash	30	150	700	#2	1150	1.2
PW6	0.36	180	#2	100	500	/	/	/	700	#2	1150	0.6
KW6	0.36	180	#2	70	350	Slag	30	150	700	#2	1150	0.8
FW6	0.36	180	#2	70	350	Fly Ash	30	150	700	#2	1150	0.6
PW9	0.39	195	#2	100	500	/	/	/	700	#2	1150	0
KW9	0.39	195	#2	70	350	Slag	30	150	700	#2	1150	0
FW9	0.39	195	#2	70	350	Fly Ash	30	150	700	#2	1150	0
PC0	0.30	180	#2	100	600	/	/	/	700	#2	1150	1.4
KC0	0.30	180	#2	70	420	Slag	30	180	700	#2	1150	1.6
FC0	0.30	180	#2	70	420	Fly Ash	30	180	700	#2	1150	1.4
PC3	0.33	180	#2	100	545	/	/	/	700	#2	1150	1.2
KC3	0.33	180	#2	70	381	Slag	30	164	700	#2	1150	1.4
FC3	0.33	180	#2	70	381	Fly Ash	30	164	700	#2	1150	1.2
PC9	0.39	180	#2	100	462	/	/	/	700	#2	1150	0.6
KC9	0.39	180	#2	70	323	Slag	30	139	700	#2	1150	0.8
FC9	0.39	180	#2	70	323	Fly Ash	30	149	700	#2	1150	0.6

* This concrete has 1.5% $NaNO_2$ by cement weight.

Proportions and Test

The codes and proportions of concrete are shown in Table 4.

The specimen of concrete permeability is $\phi 10 \times 5$ cm; it is demolded 24 h after formed (the concrete specimen of Code 1 has two states: one of normal mold removal, the other of some man-made microcracks caused by punching when it is demolded), and cured in water with temperature of 20 ± 3°C until the age of testing (7–130 days).

The sealing procedures and solutions used are the same as that specified by ASTM C1202. In the test, the resistance of the specimen is first measured by a bridge and the alternating

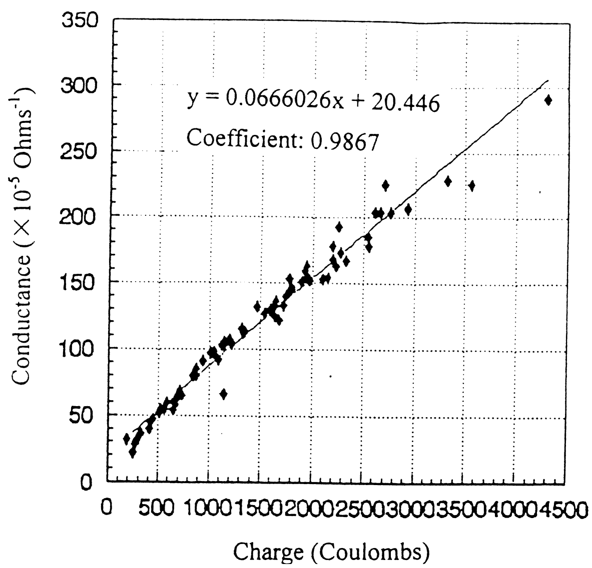

FIG. 1.
Relation between the conductance of alternating current method and charge of ASTM C1202.

current of 1 V and 1 kHz, then the ASTM C1202 measurement taken. For each age, two specimens are used, and their average is the result.

Correlation and Specifications

The resistance of the specimen measured by alternating current is converted into conductance (the inverse of the resistance), and a linear fitting is made with the conductance and the charge of ASTM C1202, as shown in Figure 1, from which good correlation can be seen, with the coefficient of 0.9867.

From the correlation and the specification of ASTM C1202, concrete permeability can be evaluated by the alternating current method as in the right side of Table 5, and, if minor differences are omitted, the specification of the alternating current method comes out as Table 6.

TABLE 5
Evaluation of concrete permeability.

ASTM C1202		Alternating Current Method	
Charge (Coulombs)	Permeability of Chloride	Conductance ($\times 10^{-5}$ Ohms^{-1})	Resistance (Ohms)
>4000	High	>287	<348
2000–4000	Moderate	154–287	649–348
1000–2000	Low	87–154	1149–649
100–1000	Very Low	27–87	3704–1149
<100	Negligible	<27	>3704

TABLE 6
Specification of concrete permeability measured by alternating current.

Resistance (Ohms)	Permeability
<350	High
650–350	Moderate
1150–650	Low
3700–1150	Very Low
>3700	Negligible

Conclusion

In the test of permeability for various concretes, the conductance gained from the alternating current method and the charge from ASTM C1202 correlate well, with the coefficient of 0.9867.

The specification of concrete permeability measured by alternating current is set up in accordance to that of ASTM C1202. As the alternating current method overcomes many disadvantages of ASTM C1202, and saves much of testing time, it hopefully will replace the later some day.

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